NOTES ON THE ANATOMY OF THE YOUNG TUBER OF IPOMOEA BATATAS LAM.[1]

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(WITH EIGHT FIGURES)

Aside from the interest in it as an economic plant and in the diseases which are so destructive to it, sweet potato (*Ipomoea Batatas* Lam.), like many of the Convolvulaceae, has an unusual structure in its thickened roots. The anatomy of certain thickened stems and roots has been investigated; but, so far as the writer has been able to discover, *Ipomoea Batatas* has received little attention.

Historical

The sweet potato has many scientific names (1, p. 323), among which *Ipomoea Batatas* Lam. (6), *Batatas edulis* Choisy (1), and *Convolvulus Batatas* Linn. (5 and 12) are the most familiar. The origin of *I. Batatas* is unknown (7), but records of its history in early literature have been written by DECANDOLLE (4), GRAY and TRUMBULL (8), and STURTEVANT (19).

DECANDOLLE (4) cites TURPIN (20) as having produced convincing figures showing that the thickened underground parts of *I. Batatas* are roots and not stems. The figures are those of entire tubers, both young and old, and they are given for comparison with the stem tubers of *Solanum tuberosum* and *Helianthus tuberosus*. With the rarest exceptions, the tubers of the sweet potato have been considered roots, but KAMERLING (10) has recently taken up the question anew. He reviews the literature in which the sweet potato is mentioned as having thickened roots, and names HAAK as a writer who considers these tubers thickened stems. Though KAMERLING did not investigate the young tuber, he regards the tuber of the sweet potato as a thickened stem and not a root, and gives figures upholding this view. Following KAMERLING, TUYIHUSA (21) essentially agrees with him.

[1] Contribution from the department of Agricultural Botany, Nebraska Agricultural Experiment Station.

This is the extent of the literature bearing directly on the anatomy of the tuber of *I. Batatas*, but other species of the Convolvulaceae have been studied, and in addition fleshy roots in other families, some of which to a certain degree resemble structurally the fleshy root of *I. Batatas*.

In 1870, VAN TIEGHEM (22) studied the roots of *Convolvulus tricolor*. He states that there are 4 rays of xylem, and that the lateral roots are formed in 4 rows corresponding to these rays. He describes and figures a tetrarch root and also the secondary tissues which are formed later. Here, also, there is a separation of the vessels by thin-walled parenchyma cells, such as may be seen in the early stages of thickening of the root of *I. Batatas*.

SCHMITZ (15), in his extensive study of the roots of the Convolvulaceae, omitted *I. Batatas*. Of those which he investigated, *Radix Scammonia*, the fleshy root of *Convolvulus Scammonia*, and *I. Turpethum* most closely resemble *I. Batatas*. He discusses the laticiferous vessels and states that they develop directly from the cambium and not from sieve tubes, as stated by A. VOGL.

WEISS (23) did not consider the Convolvulaceae in his studies of fleshy roots, but his descriptions and figures of *Bryonia dioica* show a concentric arrangement of cambium around strands of xylem, similar to that found in the thickened root of *I. Batatas*.

PETERSON (13) investigated *I. Batatas* as to the bicollateral structure of the stem; but he did not discuss the root. He mentions the internal phloem of the stem as being strongly developed, and this feature is also characteristic of the older roots.

DEBARY (3) reviews SCHMITZ's work, but adds nothing of importance concerning the anatomy. He makes a distinction between the laticiferous tubes, such as are found in the Euphorbiaceae, and the resin sacs of the Convolvulaceae.

SCOTT (16), in his paper on the anatomy of *Ipomoea versicolor*, considers chiefly the anomalous structure found in the transition region between the bicollateral stem and the root.

CZAPEK (2) reviews the literature on the laticiferous system in the Convolvulaceae. He studied the development of the system in many species, and, with the exception of *Dichondra*, he found cross-walls always present.

SOLEREDER (18) likewise refers to the work of SCHMITZ, and he gives a figure of the cross-section of the root of *Convolvulus Scammoniae*, which also has concentric layers of cambium surrounding strands of xylem.

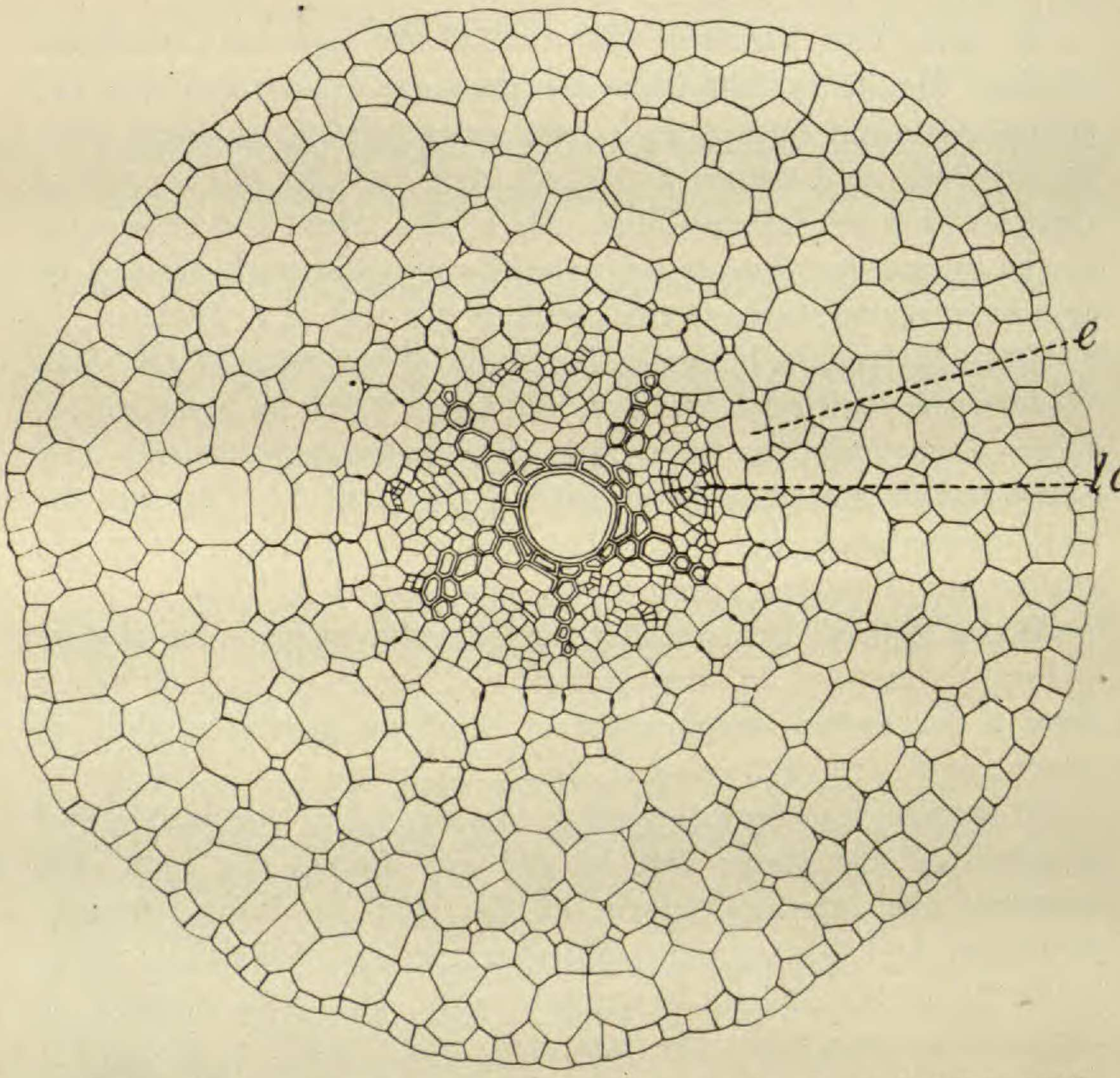

FIG. 1.—Transverse section of young root: *e*, endodermis; *lc*, laticiferous cell; ×188.

HABERLANDT (9) cites CZAPEK'S work, and in brief he characterizes the laticiferous tubes of the Convolvulaceae as follows: "Ihr Inhalt besteht aus einem Plasmaschlauch und Milchsaft von unbekannter Zusammensetzung. Nach beendtem Langswachstum des betreffenden Internodiums werden die Schlauchreihen entleert und zusammengepresst."

Reed (14), in his studies of tubers, considers only the stem tubers of *Solanum tuberosum* and *Helianthus tuberosus*.

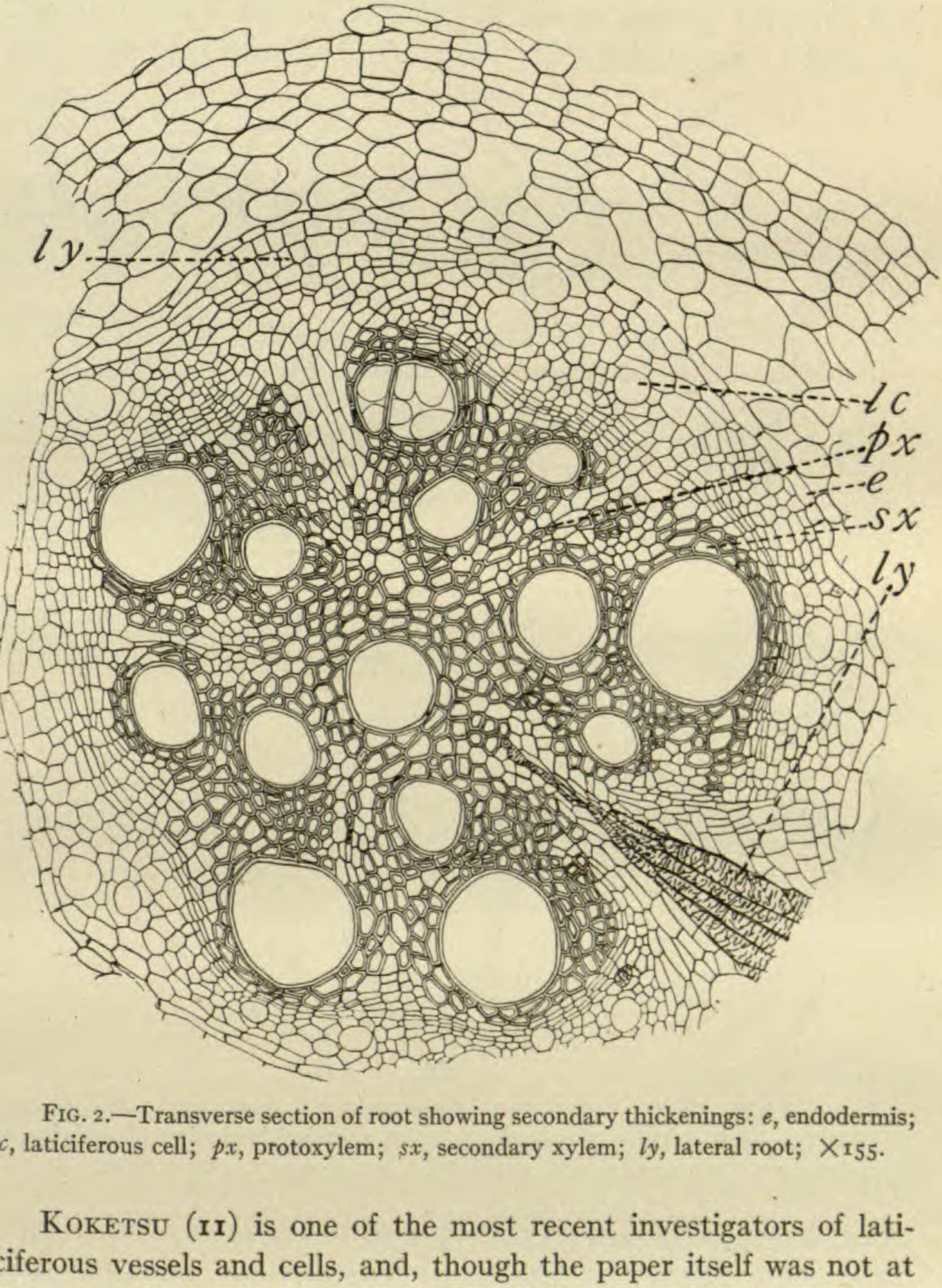

Fig. 2.—Transverse section of root showing secondary thickenings: *e*, endodermis; *lc*, laticiferous cell; *px*, protoxylem; *sx*, secondary xylem; *ly*, lateral root; ×155.

Koketsu (11) is one of the most recent investigators of laticiferous vessels and cells, and, though the paper itself was not at hand, a review states that his results uphold those of former workers. He also gives a chemical analysis of the lactic fluid.

Investigation

Sections from many varieties of the sweet potato were examined, but the present study is confined to the Yellow Jersey. Although a comparative study was made of all stages of roots, from

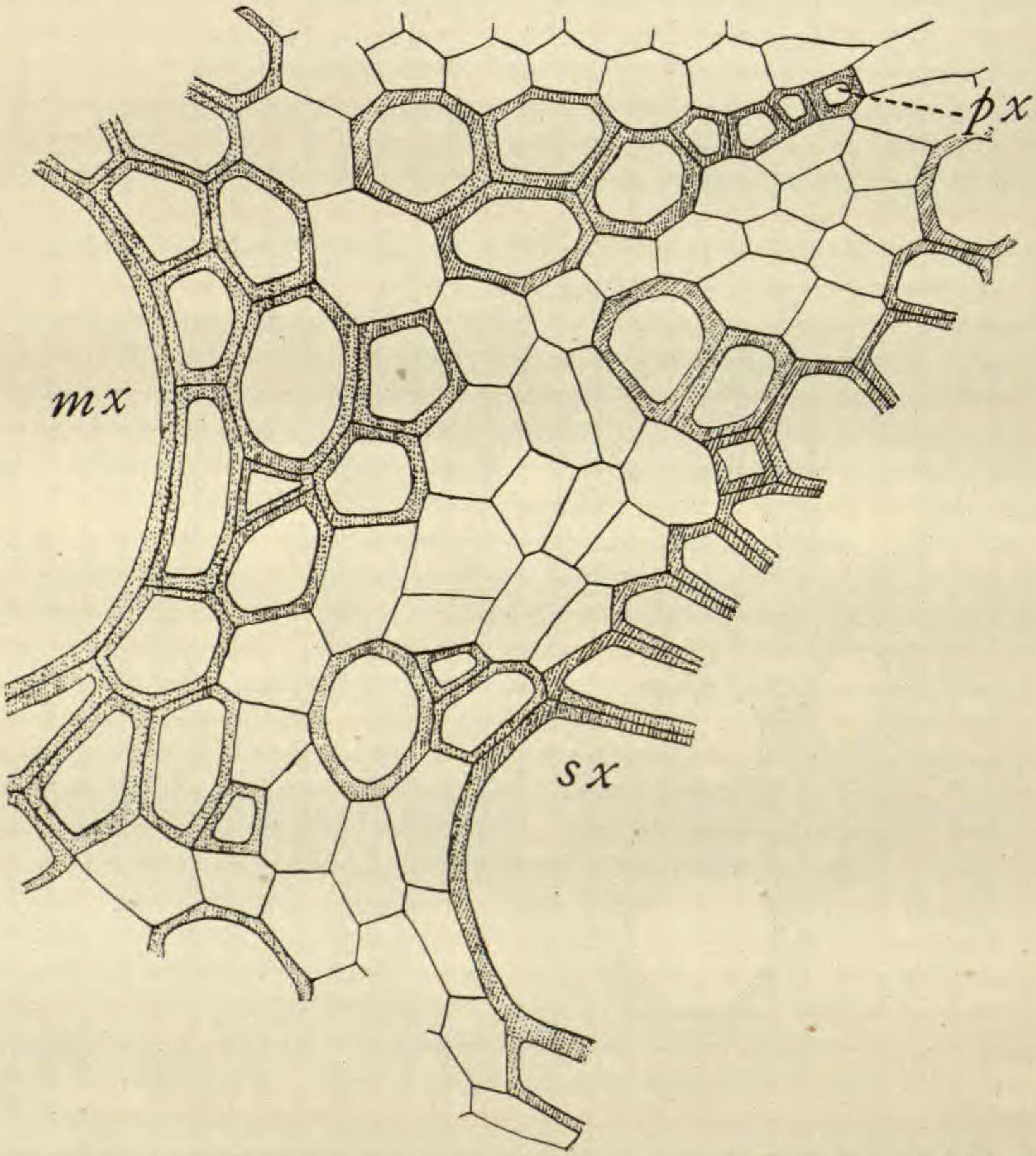

FIG. 3.—Part of transverse section of root showing beginning of activity of parenchyma: *px*, protoxylem; *mx*, metaxylem; *sx*, secondary xylem; ×810.

those showing no thickening whatsoever to the mature tuber, only the young tubers are important, for through them alone may one expect to be able to interpret the structure of the mature potato. Fig. 1 represents a freehand section of a living root; but, with that exception, the material was killed in chromo-acetic and imbedded in paraffin. Young tubers were cut in serial sections, beginning at the stem and extending beyond the region of greatest thickening of the root. With the exception of fig. 1, all figures are

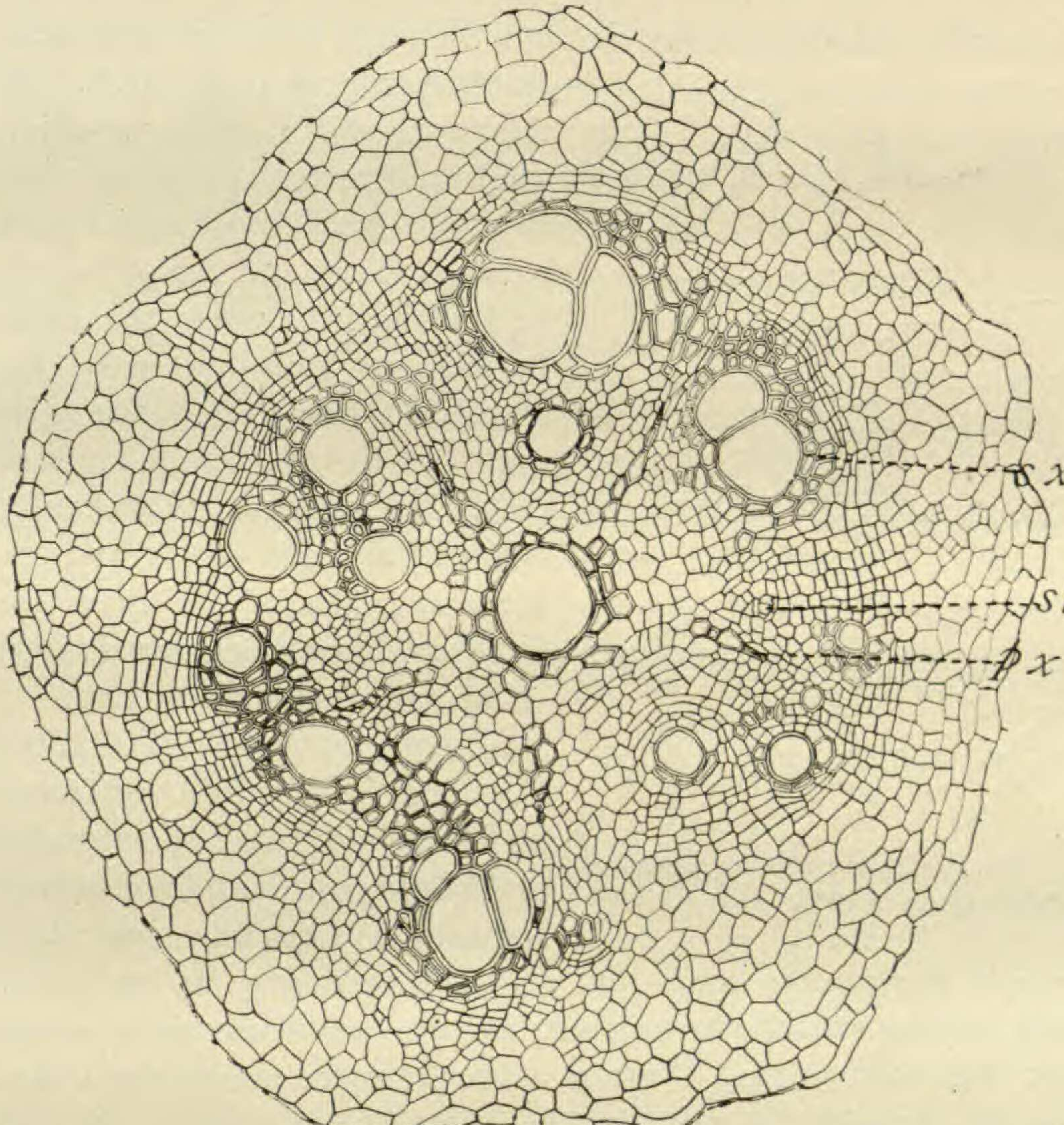

FIG. 4.—Transverse section of stele of root showing separation of xylem by parenchyma: *px*, protoxylem; *st*, sieve tube; *sx*, secondary xylem; ×155.

intentionally from the same tuber, but sections from many other tubers verify the essential features of the results here given. Some distortion must necessarily accompany such localized and greatly increased amount of thickening, but in that respect only does the structure of the fully matured tuber differ from that shown in fig. 8. In this study no attempt was made to trace the relationship between the vascular system of the stem and that of the root, as has been done by SCOTT and BREBNER (**17**) and others in some plants having bicollateral stems.

PRIMARY STRUCTURES.—The smallest roots of *I. Batatas* are frequently triarch or tetrarch; but the large roots are polyarch, chiefly pentarch or hexarch. In the young root there is usually a solid arrangement of vessels with no thin-walled parenchyma between them, and the phloem is well defined between the rays. Laticiferous cells are early distinguished (fig. 1, *lc*). The pericycle consists of a single layer of cells. The endodermis has sharply defined Casperian bands, and the remaining cells of the cortex are large and have conspicuous intercellular spaces between them.

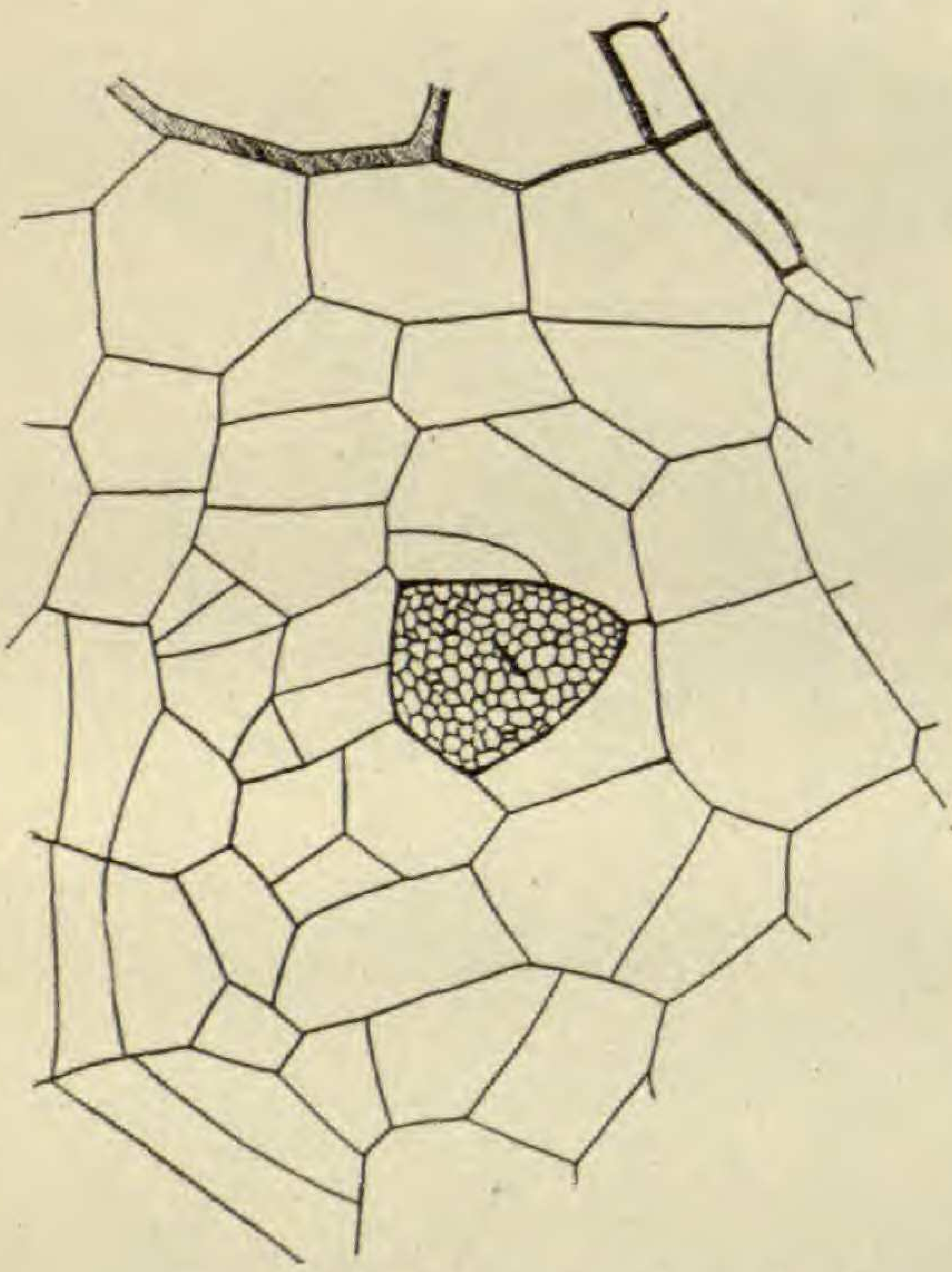

FIG. 5.—Phloem showing a horizontal sieve plate; ×1680.

SECONDARY STRUCTURES.—Cambium is organized very soon, and there is formed an extensive secondary growth which in every respect is like the secondary growth common in roots (fig. 2). The secondary xylem forms solid masses around the primary xylem; but wherever a lateral root has been formed, there is a break in the secondary xylem directly opposite the ray, for the lateral roots connect directly with the protoxylem points. These breaks, like greatly widened medullary rays, extend for some distance on each side of the place of attachment of the lateral root. It was long ago shown (**22**) that there may be as many rows of lateral roots as there are protoxylem points, and this explains the definite rows of lateral roots seen even in the fully matured potato. The amount of the secondary xylem probably is largely dependent upon conditions for growth. One root, which had grown above ground and was quite green, had an excessive amount of secondary xylem compactly arranged around primary xylem. The structure, such as shown in fig. 2, extends in this particular root about 6 cm. beyond the place of attachment of the root of the stem, but within a short distance from this point thin-walled parenchyma between the vessels becomes active (fig. 3). The parenchyma rapidly increases in amount and separates the xylem more and more into strands, consisting of one to several vessels in a strand (fig. 4). Around each strand the parenchyma is organized into concentric layers of cambium. These secondary cambiums are capable of forming both xylem and phloem, though the primary cambium has not in the meantime become wholly inactive, but throughout the growth of the root continues forming scattered strands of xylem and phloem, each of which in turn becomes surrounded by a cambium. Tyloses are common and often the vessels are completely filled with them.

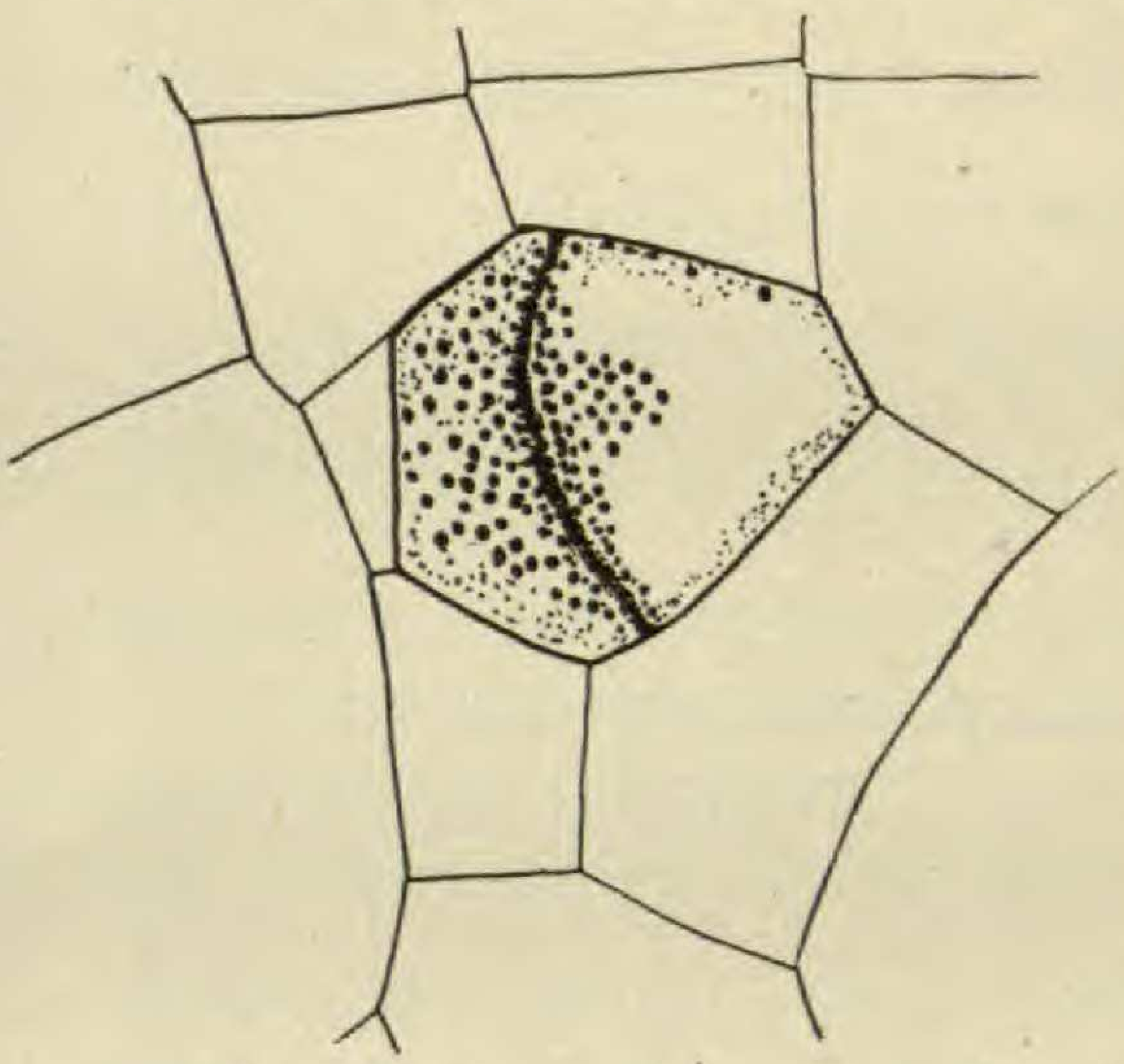

FIG. 6.—Sieve tube with inclined sieve plate; ×1680.

PHLOEM.—The phloem is rich in sieve tubes with prominent companion cells. The sieve plates are horizontal (fig. 5) or sharply inclined, so that in transverse sections they may be readily overlooked (fig. 6). Interxylary phloem appears very soon after the thin-walled parenchyma becomes active between the vessels, and apparently it may be formed before a definite cambium is organized (fig. 5). Even in

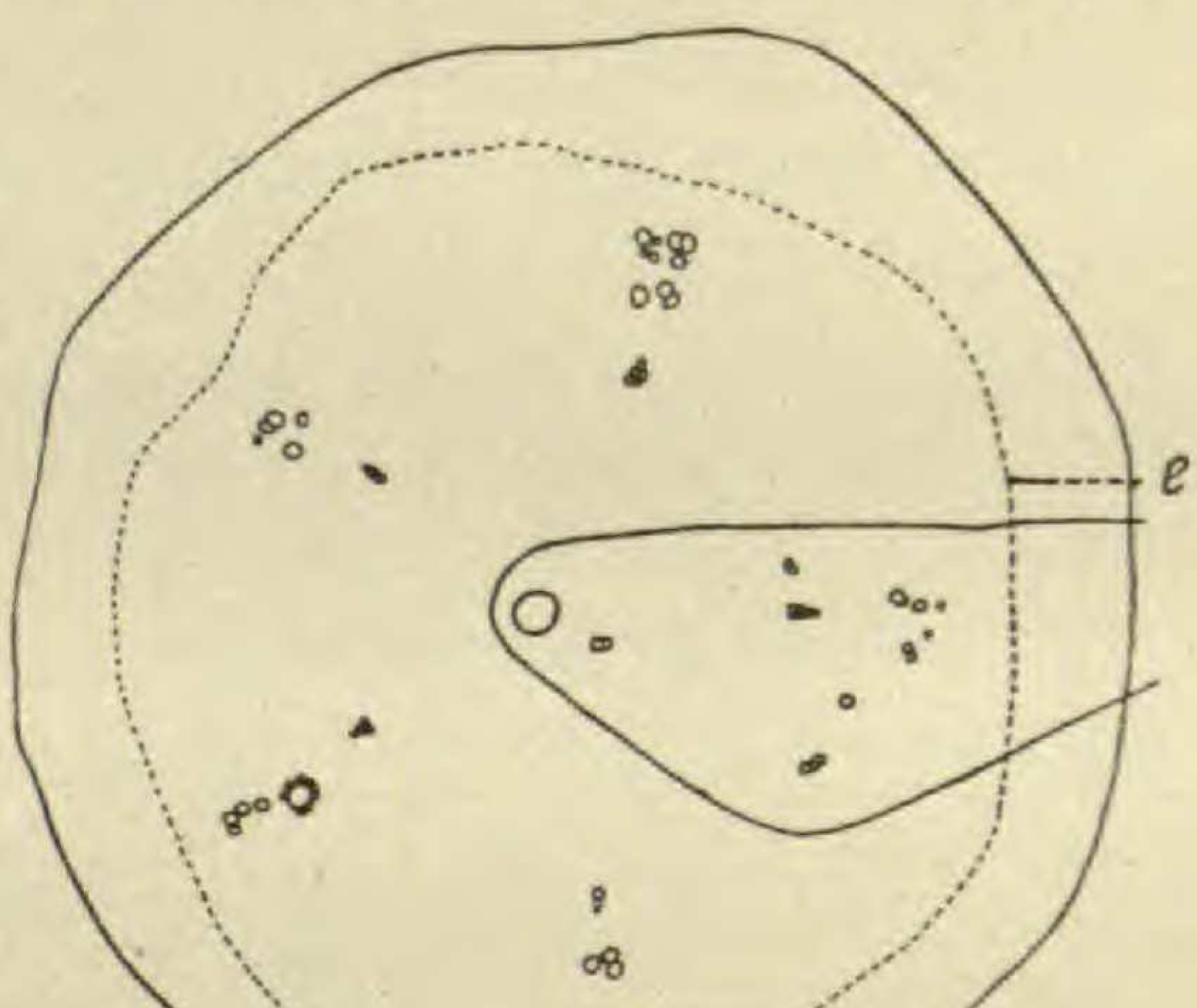

FIG. 7.—Outline of transverse section of root showing the region of fig. 8: *e*, endodermis; ×35.

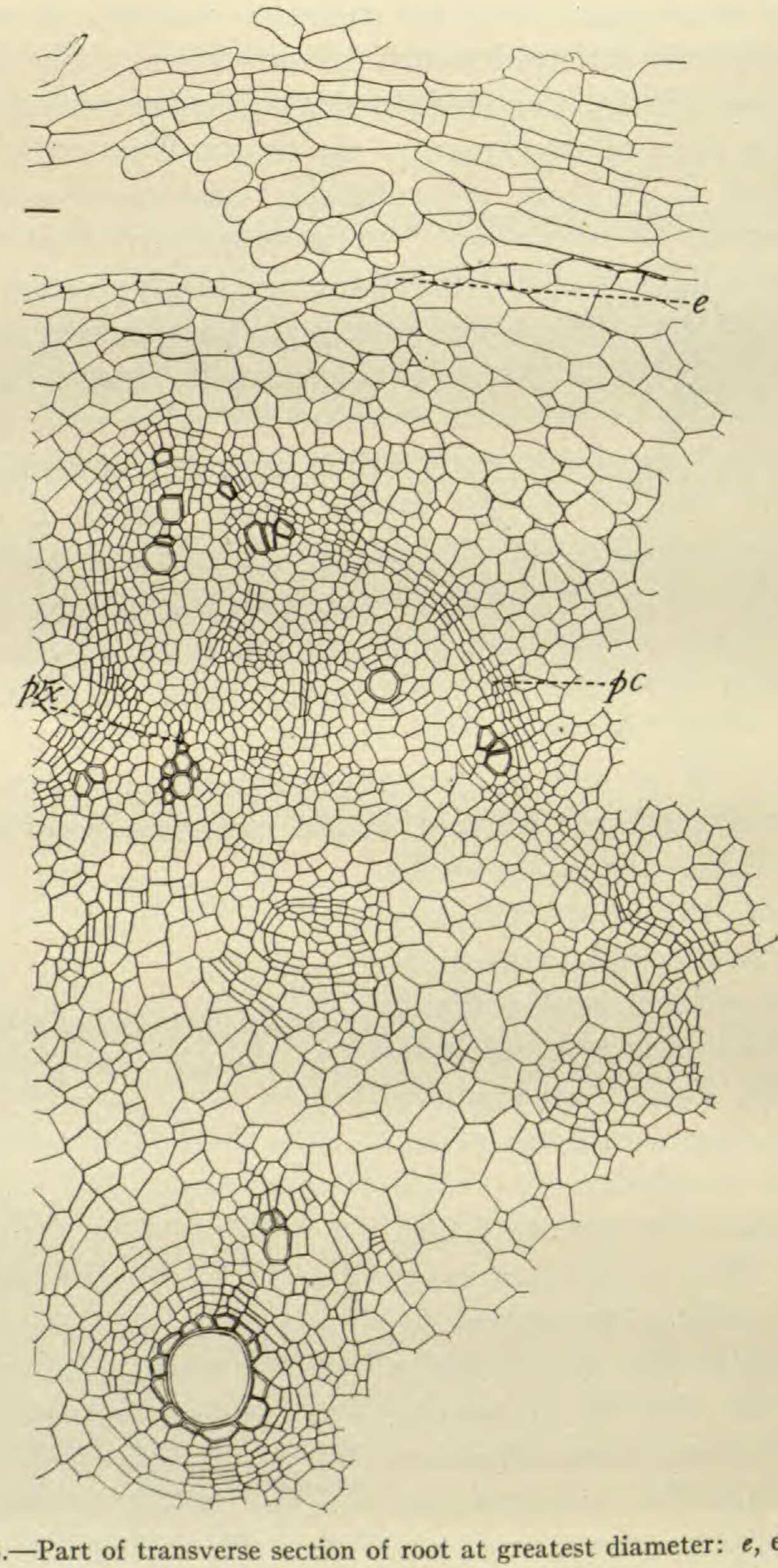

FIG. 8.—Part of transverse section of root at greatest diameter: *e*, endodermis *px*, protoxylem; *pc*, primary cambium; ×155.

a mature tuber strands of phloem unaccompanied by xylem are common.

In the young roots of *I. Batatas* the laticiferous cells are sharply delimited; but in the older tubers, in which the parenchyma cells are larger, they are not readily distinguished. The cross-walls are numerous and are not resorbed.

Summary

1. The larger roots of *Ipomoea Batatas* Lam. are polyarch, chiefly pentarch and hexarch.

2. Secondary thickenings occur in the usual way and there is formed a massive structure of secondary xylem.

3. Secondary cambiums are organized around strands of xylem and phloem which are separated by thin-walled parenchymatous cells. The primary and secondary cambiums are capable of forming xylem and phloem in isolated strands. One may reasonably expect that, if the conditions for growth are especially favorable, the secondary cambiums may be organized earlier.

4. A section of a mature tuber shows a structure consisting chiefly of parenchyma, and mingled with the parenchyma are strands of xylem, which consist of one to several vessels, and may or may not be accompanied by phloem. Each strand is surrounded by a cambium. There may also be seen strands of phloem unaccompanied by xylem. This structure may be definitely traced back to the radial protostele.

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